LEAN MANUFACTURING APPROACH IN AIRCRAFT MAINTENANCE REPAIR AND OVERHAUL

Gabriela NANOVA[1], Lubomir DIMITROV[1], Todor NESHKOV[1], Charis APOSTOLOPOULOS[2], Panayiotis Th. SAVVOPOULOS[2]

[1] Technical University of Sofia, Bulgaria

[2] University of Patras, Greece

Abstract. This paper aims to give an overview of the LEAN approach and more specifically its application in an Aircraft Maintenance, Repair and Overhaul business. There are some examples provided to make the picture more understandable in the field of the diagnosis of an enterprise which is going to be a subject to LEAN initiatives. The purpose is not to give a full list of the LEAN tools and practices that may be used in a production environment but more to give an overview and to provide examples for the necessity of adjustments to the standard practices. This is valid not only for a MRO (Maintenance Repair and Overhaul) but for each and every area in which LEAN is used. The main specifics of the Maintenance, Repair and Overhaul that concerns LEAN implementation are that it is project based and is dependent on the defects of the aircraft which is maintained. These are the greatest challenges when deciding to apply LEAN principles on such an environment but also may be considered as advantages. These specifics provide the LEAN practitioner with a lot of flexibility and the approach may be completely customized in order to serve the needs of the specific situation.

Keywords: LEAN, diagnosis, adjustments, MRO maintenance, repair, overhaul

1. Introduction

This paper aims to give an overview of the application of the LEAN Manufacturing approach in aircraft maintenance, repair and overhaul. The problem is that LEAN Manufacturing approach is originally developed for a production environment with pre-defined jobs steps that are continuously repeating throughout the manufacturing cycle. On the other hand the aircraft maintenance, repair and overhaul business is based on projects and is really dependent on the specific aircraft condition. This means that the major portion of the job is defect-based and can not be predicted in advance. Having in mind all those specifics a lot of adjustments has to be made on the LEAN tools and principles in order to apply them in the aircraft MRO sector.

These adjustments may be applied not only in the aircraft maintenance but in any other maintenance. The field of application may be extended to any other sphere not only in industry but in life. This is generally valid for the LEAN philosophy – after some adjustments and customization it may be beneficial for each and every area.

Although lean principles were originally developed for manufacturing environments, they are increasingly (and successfully) being applied to service businesses, especially those with many routine processes. Application development and maintenance is a prime candidate for lean methods not only because it involves a great many processes with the potential to be optimized but also because large differences in productivity among organizations suggest that some are far less efficient than others [1].

This was originally stated for IT sector but is fully valid for Aircraft Maintenance, Repair and Overhaul.

Recently, lean techniques have moved from manufacturing plants to operations of all kinds, everywhere: insurance companies, hospitals, government agencies, airline maintenance organizations, high-tech product-development units, oil production facilities, IT operations, retail buying groups, and publishing companies, to name just a few. In each case the goal is to improve the organization's performance on the operating metrics that make a competitive difference, by drawing employees into the hunt to eliminate unneeded activities and other forms of operational waste [2].

2. LEAN Basics

2.1. Definitions

Lean Manufacturing, lean enterprise, or lean production, often simply, "Lean," is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. Working from the perspective of the customer who consumes a product or service, "value" is defined as any action or process that a customer would be willing to pay for [3].

A lean organization understands customer value and focuses its key processes to continuously increase it. The ultimate goal is to provide perfect value to the customer through a perfect value creation process that has zero waste [4].

The definition of lean is multifaceted. It generally relates to those best processes and practices, which optimize resources and yield the best products in the fastest manner and at the lowest cost. It is an umbrella for total quality management, continuous improvement, zero defects, and all the other terms we've used and heard to describe doing things right the first time, and doing it right every time. It is not an instant transition nor is it an extension of traditional thinking or techniques. In fact, it is a revolutionary thought process that requires abandonment of some old paradigms. To think lean is to switch from internally focused thinking to externally focused thinking [5].

The secret of successful LEAN implementation is the adjustments to the specific customer's requirements. Let's consider a high-mix, low-volume manufacturer attempting to implement lean. Let's suppose they make highly complex electro-mechanical assemblies with demand for about one unit every other day across all varieties. They might read some books on lean manufacturing and attempt to implement the tools and principles in their organization. They might try to create one-piece flow cells and falsely conclude that they work only for low-mix, high volume situations. This is because they might have read that they need to calculate takt time, design the cell such that parts are delivered to the cell every 30 to 60 minutes, finished goods are removed from the cell every 30 to 60 minutes, etc. These "requirements" of lean are not really requirements but are specific applications of the concept of "one-piece flow" for a high-volume producer. These "requirements" will not work for a low-volume producer as presented. For example, if they need to produce one finished unit per day, they won't need to deliver parts to the cell every 30 to 60 minutes. In fact, they might consider kitting parts (or at least those parts that are not common to each product) and delivering those parts to the cell daily based on customer requirements [6].

Lean thinking, according to Womack and Jones, is the antidote to waste. "It provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively" [7].

The core idea is to maximize customer value while minimizing waste. Simply, lean means creating more value for customers with fewer resources.

Taking small but sustainable steps is also important for the general success of LEAN. On the picture below a graphical representation of the LEAN transformation may be seen.

Figure 1. LEAN Transformation [8]

2.2. Five LEAN principles [10]

- Specify value from the perspective of the customer - Specify what does and what does not create value from the customer's perspective and not from perspectives of individual firms, functions and departments.
- Identify the value stream - Identify all the steps necessary to design, order and produce the product across the whole value stream to highlight non value adding waste.
- Make the value creating steps flow - Make those actions that create value flow without interruption, detours, backflows, waiting or scrap.
- Produce on a pull principle - Only make what is pulled by the customer
- Eliminate defects - Strive for perfection by continuously removing successive layers of waste as they are uncovered.

2.3. Seven types of waste

Waste elimination is one of the most effective ways to increase the profitability of any business.

Processes either add value or waste to the production of a good or service. To eliminate waste, it is important to understand exactly what waste is and where it exists. While products significantly differ between factories, the typical wastes found in manufacturing environments are quite similar. For each waste, there is a strategy to reduce or eliminate its effect on a company, thereby improving overall performance and quality [12].

Muda is a traditional Japanese term for an activity that is wasteful and doesn't add value or is unproductive, etymologically none + trivia or un-useful in practice or others. It is also a key concept in the Toyota Production System (TPS) and is one of the three types of waste (muda, mura, muri) that it identifies. Waste reduction is an effective way to increase profitability. A process consumes resources and waste occurs when more resources are consumed than are necessary to produce the goods or provide the service that the customer actually wants. The attitudes and tools of the TPS heighten awareness and give whole new perspectives on identifying waste and therefore the unexploited opportunities associated with reducing waste [10].

Seven deadly wastes were identified as part of the Toyota production System by Taiichi Ohno. The usual classification of the types of waste is:

- **1 Transport**

Moving products that are not actually required to perform the processing.

Each time a product is moved it stands the risk of being damaged, lost, delayed, etc. as well as being a cost for no added value. Transportation does not make any transformation to the product that the consumer is supposed to pay for [10].

Transporting product between processes is a cost incursion which adds no value to the product. Excessive movement and handling cause damage and are an opportunity for quality to deteriorate. Material handlers must be used to transport the materials, resulting in another organizational cost that adds no customer value. Transportation can be difficult to reduce due to the perceived costs of moving equipment and processes closer together. Furthermore, it is often hard to determine which processes should be next to each other. Mapping product flows can make this easier to visualize [12].

- **2 Inventory**

All components, work in progress and finished products that are not being processed.

Inventory, be it in the form of raw materials, work-in-progress (WIP), or finished goods, represents a capital outlay that has not yet produced an income either by the producer or for the consumer. Any of these three items not being actively processed to add value is waste [10].

Work in Progress (WIP) is a direct result of *overproduction* and *waiting*. Excess inventory tends to hide problems on the plant floor, which must be identified and resolved in order to improve operating performance. Excess inventory increases lead times, consumes productive floor space, delays the identification of problems, and inhibits communication. By achieving a seamless flow between work centers, many manufacturers have been able to improve customer service and slash inventories and their associated costs [12].

- **3 Motion**

People or equipment moving or walking more than is required to perform the processing.

As compared to Transportation, Motion refers to the producer, worker or equipment. This has significance to damage, wear and safety. It also includes the fixed assets and expenses incurred in the production [10].

This waste is related to ergonomics and is seen in all instances of bending, stretching, walking, lifting, and reaching. These are also health and safety issues, which in today's litigious society are becoming more of a problem for organizations. Jobs with excessive motion should be analyzed and redesigned for improvement with the involvement of plant personnel [12].

- **4 Waiting**

Waiting for the next processing step.

Whenever goods are not in transport or being processed, they are waiting. In traditional processes, a large part of an individual product's life is spent waiting to be worked on [10].

Whenever goods are not moving or being processed, the waste of waiting occurs. Typically more than 99% of a product's life in traditional batch-and-queue manufacture will be spent waiting to be processed. Much of a product's lead time is tied up in waiting for the next operation; this is usually because material flow is poor, production runs are too long, and distances between work centers are too great. Goldratt (*Theory of Constraints*) has stated many times that one hour lost in a bottleneck process is one hour lost to the entire factory's output, which can never be recovered. Linking processes together so that one feeds directly into the next can dramatically reduce waiting [12].

- **5 Overproduction**

Production ahead of demand.

Overproduction occurs when more products is produced than is required at that time by your customers. One common practice that leads to this muda is the production of large batches, as often consumer needs change over the long times large batches require. Overproduction is considered the worst muda because it hides and/or generates all the

others. Overproduction leads to excess inventory, which then requires the expenditure of resources on storage space and preservation, activities that do not benefit the customer [10].

Simply put, overproduction is to manufacture an item before it is actually required. Overproduction is highly costly to a manufacturing plant because it prohibits the smooth flow of materials and actually degrades quality and productivity. The Toyota Production System is also referred to as "Just in Time" (JIT) because every item is made just as it is needed. Overproduction manufacturing is referred to as "Just in Case." This creates excessive lead times, results in high storage costs, and makes it difficult to detect defects. The simple solution to overproduction is turning off the tap; this requires a lot of courage because the problems that overproduction is hiding will be revealed. The concept is to schedule and produce only what can be immediately sold/shipped and improve machine changeover/set-up capability [12].

- **6 Over Processing**

Result of poor tool or product design creating activity. Over-processing occurs any time more work is done on a piece than what is required by the customer. This also includes using tools that are more precise, complex, or expensive than absolutely required [10].

Often termed as "using a sledgehammer to crack a nut," many organizations use expensive high precision equipment where simpler tools would be sufficient. This often results in poor plant layout because preceding or subsequent operations are located far apart. In addition they encourage high asset utilization (over-production with minimal changeovers) in order to recover the high cost of this equipment. Toyota is famous for their use of low-cost automation, combined with immaculately maintained, often older machines. Investing in smaller, more flexible equipment where possible; creating manufacturing cells; and combining steps will greatly reduce the waste of inappropriate processing [12].

- **7 Defects**

The effort involved in inspecting for and fixing defects.

Whenever defects occur, extra costs are incurred reworking the part, rescheduling production, etc. [10].

Having a direct impact to the bottom line, quality defects resulting in rework or scrap are a tremendous cost to organizations. Associated costs include quarantining inventory, re-inspecting, rescheduling, and capacity loss. In many organizations the total cost of defects is often a significant percentage of total manufacturing cost. Through employee involvement and Continuous Improvement Process (CIP), there is a huge opportunity to reduce defects at many facilities [12].

- **Other "hidden wastes"**

The waste of human talent is added at a later stage to the original 7 wastes. It is basically described like the effort to produce goods or services that the customer is not demanding or their specifications do not meet the customer's expectations.

Organizations employ their staff for their nimble fingers and strong muscles but forget they come to work everyday with a free brain. It is only by capitalizing on employees' creativity that organizations can eliminate the other seven wastes and continuously improve their performance [10].

A summary and brief description of all the wastes from LEAN point of view may be seen in the figure below:

Figure 2. LEAN wastes summary [15]

2.4. Components of the LEAN System

- **Technical System**

The technical system includes all the processes, tools, equipment and all the other physical things in the company, needed to create the value for the customer.

- **Management Infrastructure**

In the management infrastructure are included the formal structures, the processes and the systems for controlling of the resources in relation to the technical system.

- **Mindset and Behaviour**

Here are included the employees' thoughts and feelings as well as individual and group behaviour at the workplace.

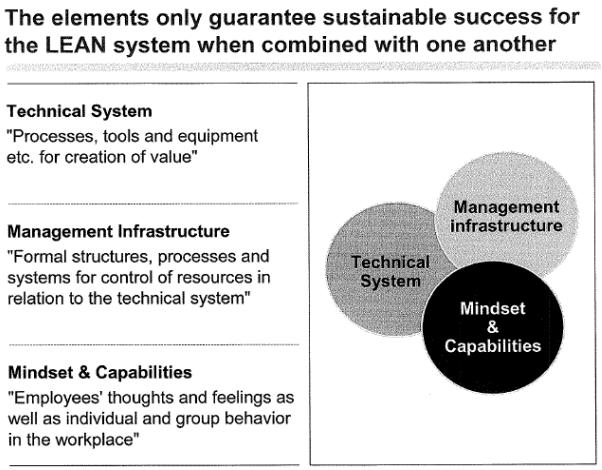

Figure 3. Three components of the LEAN system [9]

For any LEAN Initiative it is crucial to act to all the three components of the LEAN system. If the LEAN Team fails to take actions in one of the three components, the success of the overall project is questioned and seriously endangered. We could create the perfect technical system with all the equipment there at the right time, together with the perfect means to control that but when we do not have the buy-in from the employees that are going to live with the new processes daily, there is a serious chance to fail the whole project. If the people do not accept the changes and resist the new way of work it would be really hard to implement the transformed processes.

The figure 4 below shows the possible result if one of the components is missing or not fully implemented. It is crucial to focus on all the three components in order to have a system that functions properly and is taking advantage of the LEAN optimization.

2.5. LEAN Implementation

First of all, executive management must be committed to lean. If lean is a "grass roots" effort, it will have limited success. This is because lean involves so much of the organization. It involves procurement, manufacturing, quality, sales, marketing, and human resources. Each of these organizations will need to participate in the transformation. Therefore, the executives must want it. They must believe that it will improve their bottom line. If they don't, it will fail.

Figure 4. Success of LEAN depends on having all the three components in place [9]

After management has committed to implementing lean, the next step in forming a foundation for lean is communicating this commitment to the entire organization. This often missing but critical step conveys the importance of the program to the employees. Company newsletters, e-mail, the intranet, and any other such tools should be used, but the most important means of communication is having a company executive directly address the employees. The executive should explain what lean is, why the company is going to implement it, and what the next steps will be.

After the employees have been informed that this program is real and that the company is committed, the organization should begin scouting for team leaders. These are often the people that voluntarily seek to get involved in the program; the team leaders will help to train the rest of the organization. The organization should then find a change agent, often an external (or in some cases internal) consultant that can "train the trainers" and work collaboratively with management to move the program forward.

After taking these steps, an organization has an increased likelihood of initial and sustained success as a lean enterprise. Lean is not something that an industrial or manufacturing engineering group does to an organization; it is a cultural change. The importance of developing a foundation for this cultural change is critical to the success of any organization that begins a lean journey [11].

It is important to create a lean culture and not only lean processes. A few improvements make a big difference; employees are excited about initiating change in the company. People are more a part of the team, and they are more involved in

making suggestions and decisions. People are full of great ideas and will see the benefits of improvement, not only for the company but also for them. Manufacturing companies experiencing turnover problems shouldn't hesitate to do something about them. Turnover is costly, and if you can keep your employees at work and keep them happy, it is a big plus. Companies will experience a decrease in turnover expenses in a short period of time.

LEAN may be implemented by specific small improvements or as a big project touching many areas of the company at the same time (usually referred as "Transformation Project"). Usually a combined approach is used – first perform several small "just do it" activities are performed in order to prepare for a bigger initiative. This way the LEAN culture is developed step by step and trust is build in the stakeholders' minds to the LEAN philosophy and approach. As soon as the employees understand the principles, see them working in action in the daily business, they start to think by themselves if there are ways to improve their own environment.

3. LEAN in aircraft maintenance, repair and overhaul business

Maintenance, repair, and overhaul involves fixing any sort of mechanical, plumbing or electrical device should it become out of order or broken (known as repair, unscheduled or casualty maintenance). It also includes performing routine actions which keep the device in working order (known as scheduled maintenance) or prevent trouble from arising (preventive maintenance). MRO may be defined as, "All actions which have the objective of retaining or restoring an item in or to a state in which it can perform its required function. The actions include the combination of all technical and corresponding administrative, managerial, and supervision actions" [13].

The standard LEAN approach may be applied in the aircraft Maintenance, Repair and Overhaul business environment. The company firs should have processes in place and routine to some extend. On the other hand it is not recommended these processes to be a habit for years and to be already traditions. If this is a fact a lot of small initiatives are going to be necessary in order to change employees' mindset and behaviour and to get their "buy in" and to convince them that LEAN is actually developed for them to improve their own working places.

3.1. Diagnosis

It is always recommended to perform a general diagnosis of the current state of the company which is going to be a subject to LEAN initiatives. When a diagnosis is performed in a company it should be focused on the three components of the system – technical system, management infrastructure and mindset and behaviour. Having in mind the specifics of the business of aircraft maintenance mentioned before (project related and defect specific), it is obvious that not all standard LEAN tools are applicable. No matter that there are more than enough tools that may be used in order to obtain clear picture of the state from which the LEAN initiatives start. This clear picture is not only important for setting the target state that should be reached after the changes are implemented, but also is used as a basis to measure the success of the new designed processes.

A list of examples for LEAN tools that may be used for diagnosing the technical system of an Aircraft Maintenance, Repair and overhaul facility is given below:

- Five times Why – this method aims on finding the root cause of a problem it is really simple to use and consists of just asking 5 times "Why". The method helps to identify the reasons that are important and are really causing the problems seen on the surface. Usually an interview is used for applying this method.
- Pareto diagram – this method visualizes the relative significance of the problems, causes or effects. A structured view of the problems according to their importance is resulting from this analysis. It helps the LEAN practitioners to identify the problem with biggest impact and decide on which cause they have biggest chance to influence. When the first problem to act on is identified using this method the efforts are directed to the problem that would have the biggest influence and would have significant improvement potential.
- Scatter diagram – this method makes it possible to identify relations between the two variables under examination. It can also help to identify the nature of the link between the variables. Some trends may also be identified using a scatter diagram like if we have the same value of one variable each time we have another one in the other variable.
- Ishikawa diagram or Fishbone diagram – it is also known as cause-effect diagram. The aim of this tool is to identify possible causes of problems. It visualizes the different groups of problems and their

sub-categories. The usual division of the factors is: Machines; Human; Method and Material. It is a tool suitable to use for classifying the ideas coming out from a brainstorming and identifying which problems may be directly influenced by the project team.

- SIPOC diagram – the abbreviation means the most important components of the system: Suppliers Inputs Processes Outputs Customers – by these methods a comprehensive representation of the overall process is achieved. The project team may concentrate on one specific part of the process where the biggest influence and improvement of the process is expected.
- Histogram – this method provides an at-a-glance view of the location, variation and distribution of the measured value.
- Check sheet – used as a tool to help collecting the required data during the diagnosis phase.
- Shift observation is often used to identify wastes in production areas. It is a simple method of observing and recording what does an employee do during a normal working day
- GEE (General Equipment Effectiveness) = value creation / total time
- OEE (Overall Equipment Effectiveness) = value created / planned time
- Spaghetti analysis – it may be used for identification of the walking routes taken by the employees during work.
- Value stream analysis – it focuses on the process taking into account the stock levels, the routes, the turnaround and waiting times and the value creation share in the company.
- Swimming lanes – visual representation of the process together with the different roles in it.

The aim of providing this list is to show how big variety of tools may be applied to a specific industrial area which is quite different to the one from which these tools and principles originate.

3.2. Implementation

As soon as the full picture of the current state of the specific company is obtained, decision may be taken if some small activities are to be taken or a major Transformation project is needed. This decision depends to a great extent of the maturity level of the personnel and also from the scale of the desired effect. Usually it is necessary to begin with small pieces with visible effect to the direct working environment to the employees in order to obtain their trust and to gain their involvement for future bigger actions.

The usual first step to popularize LEAN philosophy is performing 5S. This is a simple and easy to implement method which rapidly affects the working environment and appearance and makes the working day easier and smoother. The 5S abbreviation stands for Sort, Stabilize, Shine, Standardize and Sustain. The aim of this method is to make the working environment tidy and ordered. This optimizes in a lot of directions like minimizing time for searching a tool for example – when following the 5S principles every tool or material has its place and is always there when not in use. This makes it easy to find what is needed in a short period of time. The 5S looks also in the frequency of usage and puts the frequently used things in immediate distance and the not so frequently used ones somewhere nearby. This makes the working place clean from things not needed so often and sets space free for things needed in everyday job. The 5S also gives clear identification of different areas in the facility – working areas, paths, storage areas and so on. The 5S toolbox includes clear ways for defining all those areas – it makes it easier to orient even when the employee has to go in a new area, different from the one he/she usually works in. The whole concept facilitates the flexibility of the people – they can be easily moved from one working place to another and the time for adaptation is minimal because the tools, equipment, materials and areas are marked the same way in the whole facility and it comes natural to find things after once used to the marking system. If 5S is used for marking the right places of tools it makes it easier to check the toolboxes at the end of the working day and identify if something is missing.

Another relatively easy to implement and with visible results tool is the Kanban system. It is used to set stores in order and to reduce stocks. Kanban means card and board in Japanese. The meaning for the production is simply a small card which is attached to parts boxes and regulates the pull system by indicating the production and delivery status for upstream process steps or warehouses. The Kanban system creates stand-alone control circuits for supplying materials and parts that are decoupled from complex control processes. These systems reduce stocks in store and by this reduce capital tie-up. The one disadvantage is that they increase transport costs.

There are four simple rules to follow when creating a Kanban system:

- the quantity of requested materials corresponds to actual demand – only materials with associated Kanban may be in circulation;

- the recipient must not place any early material requests – this means that buffer stocks are build up, which would destroy the production flow because all the capacities are matched to one another;
- the source must not produce any more than is requested otherwise this would also lead to excess production capacity;
- the delivered parts must be of perfect quality – poor quality leads to production delays at downstream due to the minimum stocks in store.

The visualization is an important part of the Kanban system, in order to indicate and to be easy to spot if transportation or production of parts is necessary.

The supermarket principle for delivery of parts is an interpretation of the Kanban methods. It consists of regular round throughout the workstations, collecting the empty containers and replacing them with full.

When there some results visible in the immediate working environment of the people it is important to set standards. Applying standards is also coming from the aim of reducing and eliminating the time for searching and trying if something could be used at some place or not. Setting standards ensures the quality of the output desired, makes the cooperation easier and makes the process steps that are carried out clear and easy to understand. It is important that the standardized work flows are documented and communicated to all employees. The standard is not permanent, it should strike for improvement. Whenever a better way is found to do some task it should be ensured by putting a new standard that the new way is used [9].

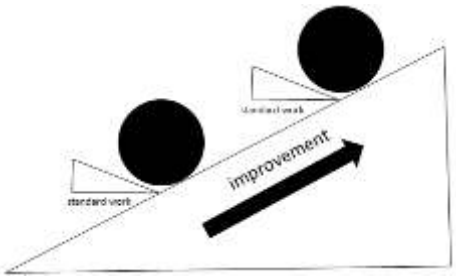

Figure 5. Visualization of standard [9]

The standards are the basis for comparison before / after. Without standards it can not be measured what has changed or what has improved. The standard is the "brake chock" that prevents from going back to the old status of the process. It also is needed because it identifies the best, simplest and safest way of doing a task known to the company at current moment.

3.3. Continuous improvement

This understanding of a standard immediately and naturally is followed by setting up a continuous improvement process. A continuous improvement mindset is essential to reach a company's goals. The term "continuous improvement" means incremental improvement of products, processes, or services over time, with the goal of reducing waste to improve workplace functionality, customer service, or product performance.

Continuous Improvement breaks down into three basic principles:

- **Challenge**: Having a long term vision of the challenges one needs to face to realize one's ambition (what we need to learn rather than what we want to do and then having the spirit to face that challenge). To do so, we have to challenge ourselves every day to see if we are achieving our goals. A quote representing this principle is *"We form a long-term vision, meeting challenges with courage and creativity to realize our dreams."*

- **Kaizen**: Good enough never is, no process can ever be thought perfect, so operations must be improved continuously, striving for innovation and evolution. This is explained in the motto *"We improve our business operations continuously, always driving for innovation and evolution."*

- **Genchi Genbutsu**: Going to the source to see the facts for oneself and make the right decisions, create consensus, and make sure goals are attained at the best possible speed. Here the guide is *"Go to the source to find the facts to make correct decisions"* [3].

Continuous improvement should happen in small increments, at all levels in the organization and across all processes in the value stream… forever onwards in the pursuit of perfection!

The instant and positive feedback for employees making improvements is a key feature of lean work and a powerful element to continuous improvement. It is important to appreciate the active participation in the continuous improvement process and to publish the success achieved by it throughout the whole company. This helps a lot in stimulating the employees to keep searching the areas with room for improvement, they have the ownership of their own working processes and feel that they have impact on how things are done in the company. The other important success factor of continuous improvement is that it should be plant-wide. Everyone should be aware of how to submit ideas for improvement and how to seek for them,

what are the wastes that should be eliminated and what are the tools for their reduction.

Everyone has a role to play, from the boardroom to the shop floor:

- To achieve continuous improvement it is necessary that the culture of the organization must change to embody the philosophy of Kaizen, driven from the boardroom down and right back up again. Only then can management allocate the resources, establish strategies, systems, procedures and organizational structures necessary for the tools of Kaizen to work.
- Middle managers are responsible for implementing Kaizen. They must monitor performance of the continuous improvement program, and ensure that employees are educated in the use of the necessary tools.
- Supervisors are responsible for applying Kaizen. They must maintain the rate of incremental by encouraging suggestions, coaching operative, and improving communications.
- Operatives must make suggestions, learn new jobs, use the tools, and generally participate in continuous improvement activities individually and in teams without fear [14].

Without active attention, the gains made through improvements in flow and process will deteriorate overtime, as customer needs and expectations change, resulting new wastes will appear. So Kaizen involves building on past gains by continuing experimentation and innovation every single day.

3.4. Sustainability

It is often falsely understood that the improvements once made should stay the same forever. This contra verses the lean principle of continuously strive to be better and to reduce and reduce waste during operation. There are several ways to sustain the changes made and to stimulate the improvement thinking of the employees in order to facilitate the new ideas for improvement.

The first thing to do in order to create a sustainable environment is to set visual standards. They should represent the KPIs (Key Performance Indicators) of the whole company, customized to each level. Different visual methods and detail level are used for the different hierarchical levels but the idea should be common for all of them. It is important that all the KPIs are understandable, easy to update and their format is helping to identify trends. When visual standards for the KPIs are implemented the lean team may be certain that all the employees have the chance to understand what the operating standards are and how is the performance of an area aligning to them. This approach facilitates the identification of hidden waste – it is easy to assume that there is something wrong if one area for example is never able to meet the target for performance.

The second step is to create visual means of communication. The usual case when changes are made to a process is that there are some minor problems arising. It is the human nature to choose the path involving the smallest amount of efforts. If there is no clear system to communicate and smooth these minor problems the employees just step back to the way it was before and just use the old process. A way to eliminate that is providing the people with a tool for communicating such items and their own ideas of how things should be. Everyone should know how to proceed if he/she spots a problem – who to contact, what to say, etc.

The third and probably the most important component of forming a sustainable system is to create a “no blame” working environment. It is important that the employees feel that the point is not in searching for the guilty person but in identifying the problem in the system. The attitude should be that the errors occur only because the system lets them occur. The finger pointing should be understood as being of no help to anyone and the causes for the errors should be found. Only by this we can ensure that the employees use the two other components described above. Even if have the perfect visual standards and means for communication if the personnel is not willing to share problems and ideas these tools are of no help and meaning. When the mindset is developed and the people focus on the root causes for the problems in an open manner it is a lot easier to find solution and a better way of dealing with the issues arisen in the daily business.

3.4. Transformation project

In the best case scenario all the four steps described before are already made and the LEAN culture and thinking in place before taking a Transformation initiative. A visualization of the desired effect of the transformation project is given on Figure 5 it may be seen that the desired effect is significant and needs to be achieved in a relatively short period of time.

The standard approach with having six phases works good enough for the Aircraft maintenance business. The adjustments should be performed on the specific tools used and are not needed for the phases of the project.

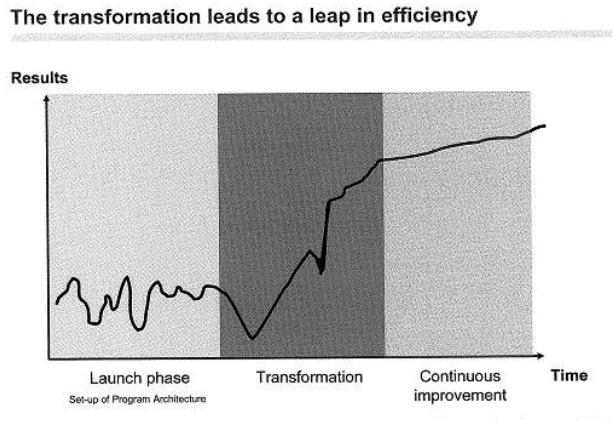

Figure 6. Transformation project [9]

On Figure 6 may be seen the transformation project divided into the regular six phases: preparation, diagnosis, design, planning, implementation, stabilization.

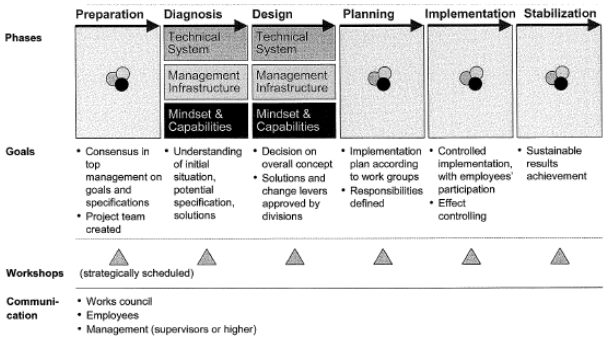

Figure 7. The six phases of a transformation project [9]

4. Conclusions and further research plans

In conclusion it is important to underline once again the benefits and challenges of applying LEAN approach to aircraft maintenance, repair and overhaul business. As it is usually stated LEAN may be applied to each and every single area of life. The challenge comes when appropriate tools should be chosen and when they should be adapted for the specific are. The biggest challenge when dealing with LEAN in a MRO is that this business is project based and is very dependent on the defects of the specific aircraft. This automatically eliminates options as using takt time for example, but provides with enough field of action in optimizing tools at point of use and work on a pull principle. These are just a few examples in order to clarify in a more clear way the extent of LEAN in such an unpredictable working environment.

The future plans and possibilities for research in the area are to take a practical approach and to focus on the options to optimize a real MRO facility with the LEAN tools. It is important to have a clear picture of the current state of application of LEAN principles, because they are continuously improving and further developing. This is not a surprise because these principles are practiced by people with the typical LEAN thinking that "There is always room for improvement!". The LEAN motto is valid not only for the companies in which we implement LEAN but also for the philosophy itself. This viewpoint provides us with the understanding that the area is not going to reach a certain point of development which is going to be statically fixed and just applied to the companies in the future. The continuously developing approaches are going to continue adjusting to the economical environment and are going to be refined and improved.

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